Preparation of Ocean Heat and Freshwater Content Variability Estimates

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PROJECT SUMMARY

When people speak of climate they are often referring to the climate of the atmosphere at the earth's surface. This is where humankind lives and it is only natural to be concerned about the immediate space that humankind inhabits. However, in order to understand the working's of earth's climate system, and to be able to forecast changes in earth's climate system, we need to study all components of earth's climate system including the atmosphere, the world ocean, the cryosphere (earth's ice such as continental ice sheets and mountain glaciers) , the lithosphere (earths' continents) and the biosphere. Each of the components of the climate system except for the biosphere can store heat and the ocean, atmosphere, and even the cryosphere can transport heat. Both the storage and transport of heat are important processes that maintain our climate system. The biosphere does not store substantial amounts of heat but it can affect how much heat is stored within each components of earths' climate system.

Rossby (1959) suggested that the world ocean may be the dominant component of the earth's heat balance on interannual- to-decadal- time scales. Rossby did not discuss what we now term "anthropogenic" or "human-induced" warming of earth's climate system. Recent work (Levitus *et al.* 2000, 2001, 2005) has shown Rossby to be correct. Ishii et al. have duplicated these first estimates of the temporal variability of earth's heat content.

During 1955-98 the world ocean (0-3000 m depth) warmed and accounted for more than 80% of the increase in the earth system's heat content. The heat content of the world is now recognized as being a critical variable to describe the earth's climate system. Increasing greenhouse gases will result in an increase of the heat content of the earth system with most of the warming occurring in the world ocean. During 1955-2003 the upper 700 m has warmed but during 2004-2005 this layer of the world ocean cooled.

The NODC Ocean Climate Laboratory (OCL) has provided international leadership in the development of ocean profile databases to provide the data used to make the first estimates of ocean heat content during the 1955-present period. Sydney Levitus is Leader of the IOC Global Oceanographic Data Archaeology and Rescue project (Levitus *et al.,* 2004a). This project has resulted in a doubling of historical ocean temperature profiles for the pre-1991 period. Our work is exemplary of the bullet in the *Summary of user recommendation for observing system enhancements from the 2004 Annual System Review* which is **"Build the ocean profile database necessary to compute ocean heat content."**

Our work on ocean heat content has attracted considerable attention from the scientific community, Congress, and the media.

Our work has been used in published IPCC Assessments and will be used in the IPCC 2007 Assessment. Our work has also been used in an NRC Report to President Bush.

ACCOMPLISHMENTS FY2006

During FY05 the P.I. and his colleagues authored or co-authored several peer-reviewed papers that dealt with the climatological and interannual variability of heat content and salinity of the world ocean. In FY06 we have published *World Ocean Database 2005* and we are updating our ocean heat content estimates through the third quarter of 2006. Several publications are being worked on that will further document the temporal variability of the heat content of the world ocean and the variability of Salinity and freshwater. Figure 1 is an example of our most recent work and shows the time series of ocean content for the 0-700 m layer the world ocean through the end of the third quarter of 2006. After reaching a relative maximum in heat content during 2003, the world ocean cooled for two years and then begin warming through the third quarter of 2006.

Much scientific, media, and Congressional interest has been generated by studies claiming an increase in the intensity of hurricanes during recent decades consistent with an increase in sea surface temperature (SST). While SST is an important parameter of air-sea interaction it is actually upper ocean heat content that is physically meaningful. Figure 2 shows the time series of the globally, zonally-integrated heat content in the 0-100 m layer for the world ocean. Clearly there has been a long-term warming trend that encompasses the entire world ocean. Also apparent in this figure is the change in temperature structure of the Pacific Ocean during El Nino and La Nina phenomena and possibly during the reversal in polarity of the Pacific Decadal Oscillation.

We have continued the work of Boyer et al. (2005) who documented large-scale variability of salinity of the world ocean by computing the Equivalent Freshwater Fluxes associated with the salinity changes of the N. Atlantic Ocean during 12955-2002. We will be publishing work during the next year on this subject. Figure 3 shows this quantity for various sub-basins of the NZ. Atlantic and clearly shows the freshening that occurred in the subarctic and Nordic seas basins during 1969-1993 and the subsequent salinification since 1993 of this basin. Concurrent with these changes the rest of the N. Atlantic has become more saline during 1955-2002. This work documents the variability of earth's hydrological cycle.

The P.I. is also a Lead Author of the upcoming IPCC (2007) assessment of earth's climate system. The work published by the P.I. and his colleagues plays a prominent role in Chapter 5 of the IPCC (2007) climate change assessment.

PUBLICATIONS AND REPORTS

Boyer, T.P., J. I. Antonov, S. Levitus, R. Locarnini, 2005: Linear trends of salinity for the world ocean, 1955-1998. Geophys. Res. Lett., 32, L01604, doi:1029/2004GL021791.

Levitus, S., J. I. Antonov, T. P. Boyer, 2005: Warming of the World Ocean, 1955-2003. Geophys. Res. Lett., L02604, doi:10.1029/2004GL021592.

Boyer, T. P., J. I. Antonov, H. Garcia, D. R. Johnson, R. A. Locarnini, A. V. Mishonov, M. T. Pitcher, O. K. Baranova, and I. Smolyar, 2006: World Ocean Database 2005, Chapter 1: Introduction, NOAA Atlas NESDIS 60, Ed. S. Levitus, U.S. Gov. Printing Office, Wash., D.C. , 182 pp., DVD.

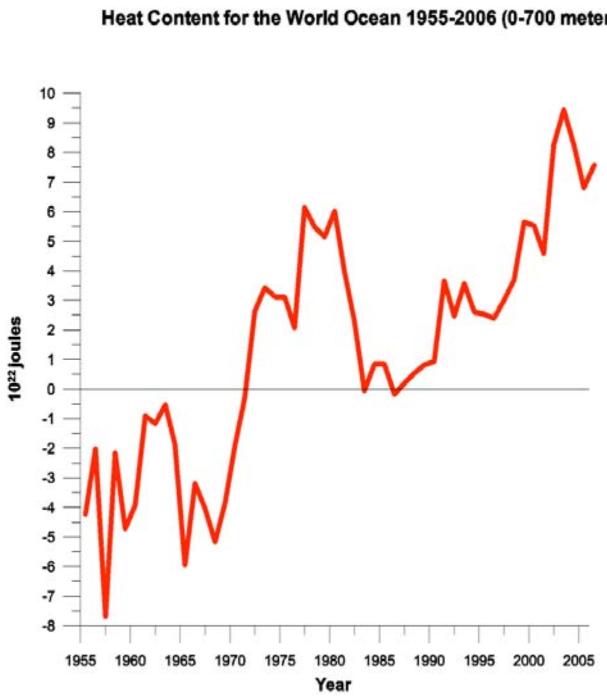

Figure 1. Time series (1955-2006 (as of the end of the 3d quarter)) of yearly ocean heat content (10^{22}J) for the upper 700 m of the world ocean.

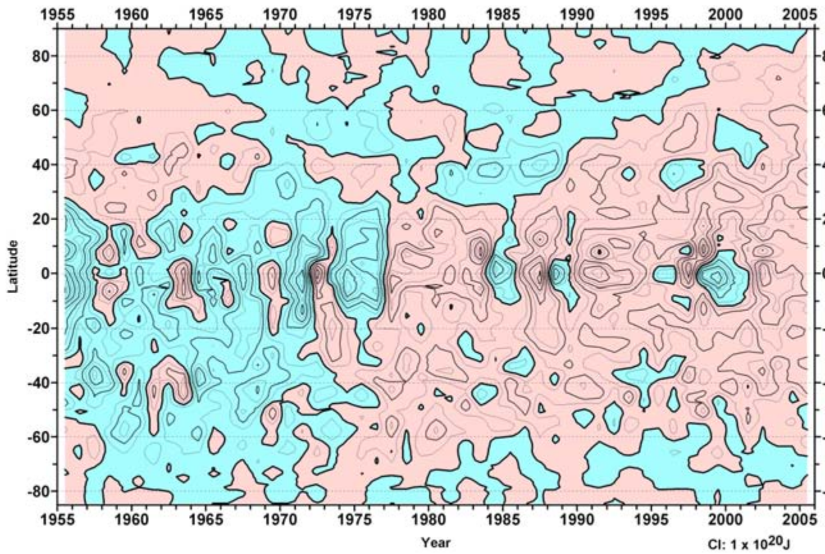

Figure 2. Global, zonally-integrated upper ocean (0-100 m) heat content (10^{20} J).

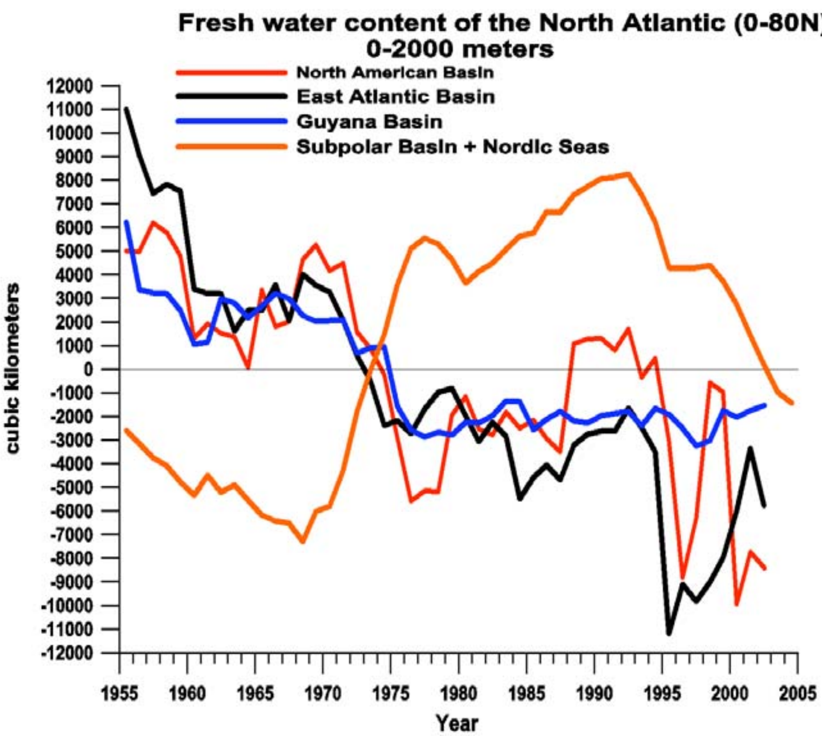

Figure 3. Variability of the Equivalent Freshwater Content of the North Atlantic Ocean and different subregions within the N. Atlantic Ocean.